



# The role of oxytocin in mothers' theory of mind and interactive behavior during the perinatal period

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**Summary** The present longitudinal study examined the relations between plasma oxytocin, theory of mind, and maternal interactive behavior during the perinatal period. A community sample of women was assessed at 12–14 weeks gestation, 32–34 weeks gestation, and 7–9 weeks postpartum. Oxytocin during late pregnancy was significantly positively correlated with a measure of theory of mind, and predicted theory of mind ability after controlling for parity, maternal education, prenatal psychosocial risk, and general anxiety, measured during the first trimester. Theory of mind was associated with less remote and less depressive maternal interactive behavior. Oxytocin, across all time points, was not directly related to maternal interactive behavior. However, there was a significant indirect effect of oxytocin during late pregnancy on depressive maternal behavior via theory of mind ability. These preliminary findings suggest that changes in the oxytocinergic system during the perinatal period may contribute to the awareness of social cues, which in turn plays a role in maternal interactive behavior.

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Oxytocin is a neuropeptide implicated in both social cognition and social behavior (Carter, 2014). Oxytocin has been associated with maternal caregiving behavior (Strathearn, 2011), which in turn is crucial for infant social and emotional development (for review see Cassidy, 2008). However, the

processes whereby oxytocin influences maternal behavior remain unclear. The present study examines whether theory of mind ability may represent a social cognitive mechanism linking oxytocin and maternal interactive behavior.

Oxytocin is a nine amino acid neuropeptide that functions as a hormone and a neuromodulator. Oxytocin is made in and acts on the brain, especially in regions involved in emotion and social interaction (Meyer-Lindenberg et al., 2011). Specifically, in humans oxytocin is synthesized in the supraoptic and paraventricular nuclei of the hypothalamus and released into the brain, where it binds to receptors in several regions including areas in the cortex, basal ganglia, thalamus, and hypothalamus (Loup et al., 1991), as well as in the amygdala (Boccia et al., 2013). Oxytocin also is transported to the pituitary gland where it is released peripherally via the bloodstream.

As research explores the neurobiological underpinnings of social behavior, a growing body of evidence points to the role of oxytocin in prosocial and affiliative behavior (Carter, 2014). While animal models consistently implicate oxytocin in parenting behavior, few studies explore the link between oxytocin and maternal caregiving behaviors and attachment relationships in humans. Plasma oxytocin levels during the perinatal period have been associated with maternal interactive behaviors (Feldman, 2012). There is an increased maternal plasma oxytocin response following mother–infant interaction, which is related to activation in oxytocin-associated brain regions (Strathearn et al., 2009) and to trait sensitivity and responsiveness to others' emotions, moods, and sensory cues (Strathearn et al., 2012). Molecular genetic research has linked oxytocin receptor gene variants to sensitive parenting (Bakermans-Kranenburg and van IJzendoorn, 2008; Feldman, 2012). These findings provide support for the role of oxytocin in maternal behavior. However, further research is needed to elucidate the mechanisms through which oxytocin influences maternal interactive behavior. We propose here that the capacity for theory of mind may be a social cognitive mechanism with implications for understanding maternal behavior.

Theory of mind is a component of social information processing which involves the understanding of mental states such as thoughts, beliefs, feelings, and desires, and how they influence behavior (Wellman et al., 2000). Theory of mind requires the cognitive ability to attribute mental states to oneself, and to infer the mental states of others (Baron-Cohen, 1989; Sodian and Kristen, 2010). The ability to interpret social cues is of particular importance to respond effectively to an infant's needs, as a mother must be able to determine those needs based on subtle cues such as facial or non-verbal signals (Ainsworth et al., 1978; Sroufe et al., 2005).

A few studies have investigated the relationship between oxytocin and theory of mind ability. The intranasal administration of synthetic oxytocin improved theory of mind, as measured by the Reading the Mind in the Eyes Test (RMET; Baron-Cohen et al., 2001), among both healthy males (Domes et al., 2007) and males with autism spectrum disorders (Guastella et al., 2010). Intranasal oxytocin also selectively improved empathic accuracy (e.g., ability to understand the thoughts and feelings experienced by others) for less socially proficient males (Bartz et al., 2010). In addition, several oxytocin receptor gene polymorphisms

are linked to theory of mind performance on the RMET (Rodrigues et al., 2009; Lucht et al., 2012). To our knowledge, research has yet to examine the influence of endogenous oxytocin on theory of mind, nor specifically in mothers.

Theory of mind may serve as a potential mechanism linking oxytocin with maternal behavior. Endogenous oxytocin may be a biomarker of social motivation and of individual sensitivity to social cues (Bartz et al., 2011). In the present investigation we examined whether plasma oxytocin levels would be related to social motivation, as manifested by positive maternal interactive behaviors, and to sensitivity to social cues, as measured by theory of mind ability. Given the importance of accurately interpreting social cues in the ability to respond appropriately to an infant's needs, we also examined whether theory of mind ability would be related to maternal interactive behavior. The present study aimed to test whether peripheral oxytocin influences maternal behavior indirectly through theory of mind ability, during the perinatal period.<sup>1</sup> Consistent with previous research examining plasma oxytocin during the perinatal period (e.g., Strathearn et al., 2012) we controlled for potential confounding variables related to child-bearing including parity, breastfeeding status, and birth control use, as oxytocin is involved in parturition and lactation.

Oxytocin also is proposed to influence social cognition and behavior via its anxiety reducing effects (Bartz et al., 2011). Oxytocin suppresses HPA axis stress hormones (e.g., Heinrichs et al., 2006), indicating a more general influence of reducing psychological and physiological reactivity to stressors. Anxiety in turn may influence RMET performance by increasing reluctance to look at others' eyes (Churchland and Winkielman, 2012) or the capacity to use information gained by eye gaze. Maternal anxiety also is related to less sensitive and more intrusive maternal interactive behavior (Kaitz and Maytal, 2005). In order to test whether theory of mind represents a unique mechanism, we controlled for anxiety, including both general anxiety and pregnancy related worry.

The effects of oxytocin on social cognition and behavior may be modulated by contextual factors and stable individual characteristics (Bartz et al., 2011). Given that oxytocin may be dysregulated by childhood trauma (e.g., Heim et al., 2009), early adversity may represent a potential moderator. In the present study, we used psychosocial risk factors (e.g., history of psychological and social problems such as depression or abuse) to control for contextual factors, and socio-demographic information to control for individual characteristics.

The current study proposes that theory of mind ability represents a social cognitive mechanism mediating the link between peripheral oxytocin and maternal interactive behavior during the perinatal period. We hypothesized a mediational model wherein (a) oxytocin is related to theory of mind and to maternal interactive behavior; (b) theory of mind is related to maternal interactive behavior; and (c) theory of mind mediates the link between oxytocin and maternal interactive behavior.

<sup>1</sup> The present investigation forms part of a larger longitudinal study on perinatal mental health, of which other data are not reported here.

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